

COLOUR DIPOLES and SATURATION

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We employ values of the colour dipole cross section extracted from electroproduction and photoproduction data to show that gluon saturation effects are not required by the current HERA data but will become important in the THERA energy region.

1 The colour dipole model

Singly dissociative diffractive γp processes are conveniently described in the rest frame of the hadron using a picture in which the incoming photon dissociates into a hadronic state which subsequently interacts with the proton. In the colour dipole model,^{1,2} the dominant states are assumed to be $q\bar{q}$ states of given transverse size. Specifically

$$|\gamma\rangle = \int dz d^2r \psi(z, r) |z, r\rangle + \dots, \quad (1)$$

where r is the transverse size of the pair, z is the fraction of light cone energy carried by the quark and $\psi(z, r)$ is the *light cone wave function* of the photon. Assuming that these states are scattering eigenstates (i.e. that z, r remain unchanged in diffractive scattering) one obtains

$$\sigma_{T,L}^{\gamma^*p} = \int dz d^2r |\psi_{\gamma}^{T,L}(z, r)|^2 \sigma(s, r, z), \quad (2)$$

for the γ^*p total cross-section in deep inelastic scattering, where $\sigma(s, r, z)$ is the total cross-section for scattering dipoles of specified (z, r) from a proton at fixed $s = W^2$. This “dipole cross-section” is a universal quantity for singly-dissociative diffractive processes on a proton target, playing a similarly fundamental role in, for example, open diffraction, exclusive vector meson production and deeply virtual Compton scattering.

2 The dipole cross-section

We have extracted the dipole cross-section from DIS and real photoabsorption data assuming a form with two terms with a Regge type s dependence and no dependence on z :

$$\sigma(s, r) = a_{soft}(r) s^{\lambda_S} + a_{hard}(r) s^{\lambda_H} \quad (3)$$

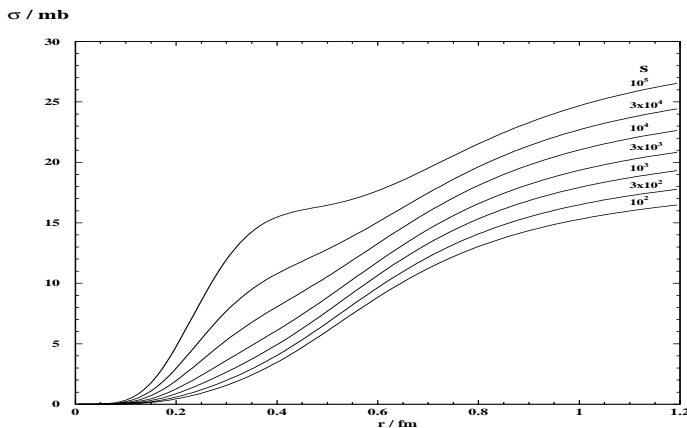


Figure 1: The dipole cross-section as a function of s in the HERA range.

where the values $\lambda_S \approx 0.08$, $\lambda_H \approx 0.42$ resulting from the fit are characteristic of the soft and hard pomeron respectively. The functions $a_{soft}(r)$, $a_{hard}(r)$ are chosen so that for small dipoles the hard term dominates yielding a behaviour $\sigma \rightarrow r^2(r^2 s)^{\lambda_H}$ as $r \rightarrow 0$ in accordance with colour transparency ideas; while for large dipoles $r \approx 1$ fm the soft term dominates with a hadronlike behaviour $\sigma \approx \sigma_0(r^2 s)^{\lambda_S}$. Further details of our approach, including the treatment of the wavefunctions, may be found elsewhere³. The resulting dipole cross-section is shown in Figure 1.

3 Saturation

For high enough energies, the assumed s^λ ($\lambda > 0$) behaviours assumed above must be tamed by unitarity effects, especially for the hard term with $\lambda_H \approx 0.4$. At fixed Q^2 , $x \rightarrow 0$ as $s \rightarrow \infty$ and the resulting softening of the corresponding $x^{-\lambda_H}$ behaviour is associated with gluon saturation in the quark-parton language. The fact that we obtain an excellent fit to the DIS data, means that the current HERA data are not at sufficiently high s to *require* the saturation effects that are built into some other similar dipole models^{4,5}. We note that our model agrees with the standard Caldwell plot Figure 2, where the turn over as x decreases occurs because Q^2 is also decreasing; no such effect is predicted in our model if x is decreased at fixed Q^2 , as confirmed by the preliminary ZEUS97 data.

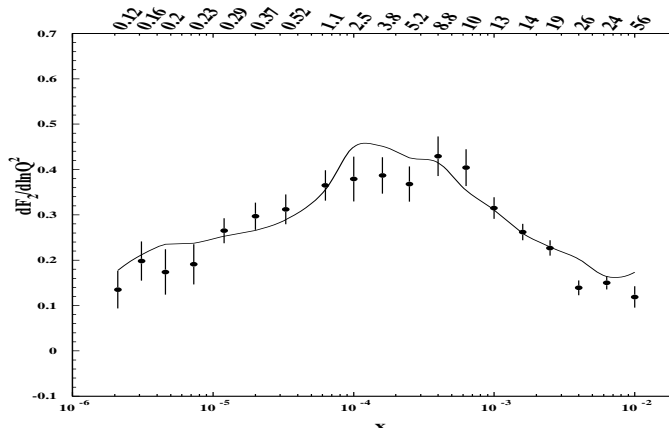


Figure 2: The Caldwell plot. Predictions are made at the Q^2 values of the data points and roughly interpolated.

A strong indication of when saturation effects will be needed is given in Figure 1. As can be seen, the cross-section for small dipoles is initially small but increases rapidly and at the top of the accessible HERA range is becoming commensurate with the slowly increasing “hadronic” behaviour of the large dipoles. It is at this point that saturation effects are expected to become important; if they don’t, the cross-section for small dipoles will exceed that for large dipoles at higher energies and the dipole cross-section will paradoxically decrease with increasing size r . Saturation effects are therefore expected to play an important role just beyond the HERA range, in the planned THERA region with $s_{max} \approx 10^6$ GeV.

References

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